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A Survey of Zinc Concentrations in Industrial Stormwater Runoff

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A Survey of Zinc Concentrations in Industrial Stormwater Runoff

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Waterbody No. WA-09-1015, Springbrook (Mill) Creek

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Abstract

Industrial facilities required to monitor and report pollutants under the Industrial Stormwater General Permit have reported high concentrations of zinc in stormwater discharges. In this study, sources of zinc are identified through (1) a literature search, (2) a survey of 28 facilities, and (3) monitoring at two facilities.

From the literature search, a list of potential sources of zinc in the environment was developed. These were narrowed down to those likely to be significant sources of zinc in industrial stormwater runoff.

Inventory surveys were conducted at 28 industrial facilities in the vicinity of Kent, Washington. Major sources of zinc were identified as galvanized materials, particularly on roof surfaces, as well as motor oil and hydraulic fluid accumulated on parking areas, loading docks, and paved grounds. Tire dust in areas with high volumes of trucks and forklifts may also be an important source.

As an indication of the efficacy of self-reported data, 20 of the 28 facilities inventoried appeared to have sampled and reported without error or bias. The facilities reporting lower zinc concentrations in their stormwater discharges were more likely to report data in ways appearing to introduce bias or error, and in the direction of under-reporting. Because of this, zinc concentrations in stormwater discharge from facilities studied, and perhaps facilities statewide, may be higher than self-reported data indicate.

Monitoring took place at one industrial facility to substantiate sources of zinc in stormwater runoff from roof, parking, and loading dock areas. All three of these areas were found to be major sources of zinc in stormwater runoff. Monitoring of two roofs was conducted at a second facility. Zinc concentrations of approximately 500 µg/L were found in runoff from the roof with galvanized ductwork; one-tenth of that concentration was found from the roof free of galvanized materials.

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- The two facilities where monitoring was undertaken, whose personnel provided extensive help.
- The 28 facilities included in the source inventory whose personnel took the time to show their sites and explain their sampling and reporting procedures.
- Jeff Davis of Tree Top for providing information about tire particles in stormwater runoff, and for providing supporting data.
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Background

Industrial facilities with permits under the Industrial Stormwater General Permit (ISGP) have been required to submit self-monitoring data to the Washington State Department of Ecology (Ecology) on a quarterly basis since 2003. All industrial facilities are required to sample for turbidity, pH, total zinc, and oil and grease. Metals such as zinc expressed as “total” are equivalent to “total recoverable” (TR) as reported by some laboratories. Data from ISGP self reports have shown elevated concentrations of zinc in stormwater discharges from many facilities. While there has been concern about the high zinc concentrations, the sources of zinc at these facilities have not been identified.

Most facilities under the ISGP have been reporting total zinc concentrations in stormwater discharge higher than the 117 µg/L benchmark specified in the ISGP. The benchmark is intended to indicate maximum pollutant not likely to cause excursions from water quality standards. Exceeding the benchmark for two consecutive quarters triggers a requirement for additional monitoring. Every quarter approximately 50% of reporting facilities have shown concentrations exceeding 117 µg/L.

In addition to the benchmark, a modification of the ISGP in December 2004 set an action level for total zinc of 372 µg/L. Exceeding this level for stormwater discharges any two of four quarters annually calls for the permittee to enact a specific response. Every quarter about 20% of reporting facilities statewide have shown concentrations exceeding the 372 µg/L action level.

Self-monitoring data from the 28 facilities surveyed in this study showed similar, though somewhat higher, zinc concentrations. Every quarter about 65% of the facilities have shown concentrations exceeding 117 µg/L and about 30% show concentrations exceeding 372 µg/L.

The issue of high concentrations of zinc in industrial stormwater discharges is not confined to Washington State. Studies in other states and nationwide have similarly found high zinc concentrations in stormwater discharges. In a study of industrial sites in North Carolina in which 20 sites from 10 industrial groups were independently sampled during the first 30 minutes of discharge, the median value for total zinc was 260 µg/L. (Line, D.E. et al., 1997). Only two of the 20 facilities showed zinc concentrations below the 117 µg/L benchmark of the Washington State ISGP.

In California, high median total zinc concentrations were found from an analysis of a large set of self-reported data: 830 µg/L from Primary Metal Manufacture (SIC 33); 700 µg/L from Metal Fabrication (SIC 34); and 280 µg/L from Transportation (SIC 41-42 - Lewis et al., 2000)

The National Stormwater Quality Database (NSQD) includes data from 3,770 separate storm events from 66 agencies from 7 states. NSQD findings show industrial total and dissolved median zinc concentrations of 210 and 112 µg/L, respectively (Pitt et al., 2004).

Urban stormwater runoff is generally of a lower zinc concentration than runoff from industrial sources. Stormwater from all sources nationwide has a median zinc concentration of 129 µg/L (pooled NURP/USGS data – Smullen and Cave, 1998). This is considerably lower than the concentrations from stormwater discharges for industrial facilities in Washington and other states, as well for the 28 facilities included in this study.

Project Description

This study investigated potential sources of zinc in stormwater runoff from facilities with permits under the ISGP. The principal study objectives were to identify potential sources of zinc at industrial sites from a literature search and to survey possible sources at a number of industrial facilities. Other objectives were to confirm potential sources of zinc through monitoring at one or more facilities, and to explore the validity and usefulness of self-monitoring data at facilities surveyed. The Quality Assurance Project Plan for this project included the analysis of copper as well as zinc. This study has been limited to zinc in order to have the resources to collect more extensive zinc data.

The facilities included in this study were in the vicinity of Kent, a city located between Tacoma and Seattle. This area was selected because of its high density of industrial sites, most within the drainage area of Mill Creek, which is known to have shown high levels of zinc during storm events. The close proximity of facilities also enabled efficient trip planning for the study.

Onsite surveys were conducted at 28 industrial facilities that have been self-reporting data to Ecology. Facility surveys and discussions of facility monitoring at each site were the basis for identifying sources of zinc and evaluating the efficacy of sampling and reporting.

In addition to identifying potential sources, the study assessed the efficacy of methods used to produce and report self-reported data from the 28 facilities. There is currently no information about the efficacy of self-monitoring data statewide. By extension, this study will provide some indication of the validity of self-monitoring data. The usefulness of self-monitoring data in aiding the assessment of individual facilities was explored through individual cases.

This study was conducted and the report is presented in four parts:

1. **Literature Review and Source Listing**: An extensive list of potential sources of zinc in the environment was developed. These sources were narrowed down to those likely to be significant sources of zinc in industrial stormwater runoff.

2. **Facility Source Inventories**: Potential sources of zinc in stormwater discharged from 28 industrial facilities were identified and assessed.

3. **Facility Monitoring**: Focused sampling at two facilities served to support the list of significant sources developed in Part 1 and identified in Part 2. Areas sampled were roofs, parking areas, and loading docks.

4. **Validity and Usefulness of Self-Monitoring Data:** Reviews of sampling sites selected by facility personnel provided the basis for evaluating the efficacy of self-monitoring at each facility. In addition, the usefulness of self-reported data in evaluating facility monitoring and pollutant sources was tested for the 28 facilities on a case-by-case basis.

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1. Literature Review and Source Listing

The objective of the literature review portion of this study was to identify potential sources of zinc in stormwater from industrial facilities. While elevated levels of zinc in industrial stormwater have been documented, little information is found in the literature concerning the sources responsible for these elevated concentrations. A discussion of sources of zinc with potential significance for stormwater runoff from industrial facilities follows.

Galvanized Metals

Galvanized materials are common at industrial facilities. Galvanization is the process of coating iron or steel with zinc. Zinc acts to protect the metal from corrosion or rust. Galvanized materials typically have a life of 30 years or more.

Several studies have monitored zinc concentrations in runoff from galvanized roofs. Concentrations of total zinc in galvanized roof runoff have been reported in a range of 1,100 – 12,200 µg/L (Good, 1993; Quek and Förster (1993); Thomas and Greene, 1993). The Port of Seattle monitored stormwater runoff from galvanized (Galvalume®) roofs at Sea-Tac International Airport and found similar concentrations: 400 – 15,000 µg/L total zinc (12,000 dissolved, maximum; Indumark, 2004).

Only one roof among the 28 facilities surveyed in this study was surfaced with galvanized metal. However, many industrial facility roofs supported galvanized metal surfaces including ductwork, heating/ventilation/air-conditioning (HVAC) equipment, ventilation fans, turbines, or pipes. The range 1,000 to 15,000 µg/L (total zinc) typical of stormwater runoff from galvanized roof surfaces may serve as an approximation of stormwater runoff concentrations from these galvanized surfaces.

Materials used for the manufacture of sewer pipes are galvanized metal, concrete, or PVC. Galvanized metal stormwater sewer pipes may be a source of zinc in runoff. Facilities affected may be those where self-monitoring samples are collected from the bottom of catch basins or manholes rather than at the lip of a catch basin or other surface runoff.

Galvanized chain-link fences surrounds the perimeter of many industrial facilities. The area of galvanized material in a chain-link fence can be considerable: A 6-ft high, 6-gauge (industrial thickness) chain-link fence has an exposed area of approximately 87 in^2 per linear inch of fence. This is equivalent to a galvanized metal roof with dimensions of 7 feet from crown to gutter per linear inch.

Parking Areas, Loading Docks, Paved Grounds

National data shows typical zinc concentrations of 225 µg/L for stormwater runoff from industrial parking lots (Claytor and Schueler, 1996). This concentration is similar to overall stormwater discharge concentrations at industrial facilities in Washington State.

Contributions of zinc to the parking areas, loading docks, and paved grounds common to industrial facility sites appear to come from three primary sources: motor oil, hydraulic fluid, and tire wear.

Motor Oil

Motor oil is known to contain high levels of zinc. Every major brand of motor oil contains zinc from 0.11 - 0.20 % zinc by weight (Hackett, 1999). This corresponds to 1,000,000 – 1,800,000 µg per /L of motor oil of 0.88 density. This concentration is high enough that motor oil diluted 1:2,500 with water results in a total zinc concentration higher than the action level of 372 µg/L specified in the ISGP.

During long periods of little or no precipitation, motor oil accumulating on paved surfaces can be considerable, though in part hidden by being absorbed by dust and dirt that also accumulates on paved surfaces.

Employee and other parking areas, as well as loading docks and grounds, may be sources of leaked motor oils contributing to an industrial facility's stormwater discharge.

Hydraulic Fluid

Hydraulic fluids contains zinc to reduce wear, at approximately the same concentration as in motor oil. The dividing line between hydraulic fluid considered to be high or low in zinc is 0.07% or more zinc by weight. Environmental concerns are beginning to drive hydraulic fluid manufacturers away from zinc, but at this time, the technology and interest have not been well developed (Travell, 2003).

Hydraulic fluid can leak from forklifts or other hydraulic equipment onto paved surfaces, becoming entrained in stormwater flow. Like motor oil, hydraulic fluids can build up on paved surfaces.

Tire Particles

Zinc is used as a filler material for tires and is found in tire material at 1% by weight. Tire tread material is released with tire wear in the form of particulate dust or deposits onto pavement. Zinc released from tire wear on roadways has been found to be a source in stormwater runoff.

The potential for considerable zinc inputs to industrial stormwater from tire dust has been pointed out by Jeff Davis, an engineer with the fruit processor, Tree Top, Inc. Fine black powder has been found coating top rails of storage shelf racking, and there has been a problem with tire dust depositing on finished goods.

At areas of Tree Tops facilities where flatbed trucks are loaded and unloaded, there is heavy 24-hour forklift traffic. Stormwater from the facilities has been reported to be inky-black in color. Davis suggested that considerable short-radius turning results in tire-dragging and a high rate of tire wear. To counter the problem, Tree Top has employed the use of non-marking forklift tires and increased ventilation (Davis, 2005a). The problem of a fine black powder or dust collecting upon warehouse inventory has been reported by other firms (Concrete News, 2005).

At the suggestion of the project lead for this study, both total recoverable (TR) and dissolved zinc concentrations were analyzed for runoff at Tree Top facilities (Davis, 2005b) . Analyses of grab samples at their Selah and Cashmere facilities from a storm event on November 1, 2005 showed the following zinc concentrations:

Selah:	181 µg/L zinc total	85 µg/L zinc dissolved	(53% of zinc as particles)
Cashmere:	256 µg/L zinc total	125 g/L zinc dissolved	(51% of zinc as particles)

A strong relationship between sideways friction and tire wear has been found in roadway situations. Estimates of tire particles released on straight sections of typical roadways are 0.01 – 0.05 g-tread/km; Councell et al., 2004; Pierson et al., 1974). This compares with much higher rates of 7 - 40 g-tread/mi (4 – 25 g-tread/km) on a 40 mph roadway curve (Pierson et al., 1974). The rate of tire wear for forklifts and trucks making tight turns on grounds and loading docks may be considerably greater. Although this source of zinc in industrial stormwater runoff is not generally recognized, it should not be assumed that the contribution of tire wear to zinc in industrial stormwater is insignificant or even small.

Atmospheric Deposition

Atmospheric deposition during dry weather (dry deposition) or carried by rainfall (wet deposition) is known to be a source of metals including zinc, but the extent is largely unknown.

A wide-ranging report reviewing studies of the significance of atmospheric deposition in highway runoff (Colman, 2001), concluded that "*none of the investigations used methods that could accurately quantify the part of highway runoff load that can be attributed to ambient atmospheric deposition. Lack of information about accurate ambient deposition rates and runoff loads was part of the problem*."

A study for the Port of Seattle of zinc sources to stormwater runoff at SeaTac Airport included an attempt to quantify zinc from aerial deposition by exposing pre-cleaned plastic guardrail and other surfaces to synthetic rainfall, but results were inconclusive, as cleaned surfaces had higher zinc concentrations than uncleaned (Taylor Associates, 2004).

The extent of atmospheric deposition depends on the extent of urbanization of an area, the presence of air pollutant sources, as well as localized weather/climate conditions. Determinations or estimates of atmospheric deposition of zinc need to be area-specific.

Other Potential Sources

A number of possible sources of zinc considered in this literature search have the potential to be found in industrial facility outdoor surfaces. These include the use of zinc oxide in paints for mildew protection and in wood coatings to reduce UV degradation.

Zinc concentrations in runoff from roofing and building materials of types other than galvanized metal have been reported as typically 30 – 500 µg/L (Boller, 1997; Good, 1993; Heaney et al., 1999; Mason et al., 1999; Quek and Forster, 1993; Thomas and Greene, 1993; Zobrist et al., 2000). This is considerably lower than zinc concentrations up to 12,000 µg/L or higher from galvanized surfaces.

The most common roofing material found in this survey was “torchdown,” a bitumen (asphalt) modified with the addition of polymer and applied with heat to flat roofs. Most often, a coating of aluminum paint covered the bitumen to reflect heat and reduce bitumen cracking. According to the Material Safety Data Sheet (MSDS) and manufacturers of aluminum paint, there is no zinc in the product. Asphalt is known to contain small amounts of zinc, but sources of zinc in highway runoff are identified throughout the literature as tire dust and motor oil, not asphalt pavements themselves.

Paints rich in zinc are sometimes applied to metal surfaces to provide galvanic protection, though this was found at only one of the 28 facilities surveyed in this study.

Landscape or lawn fertilizers are often overlooked as potential sources of zinc in industrial stormwater. Some landscape fertilizers contain roughly 0.1% as a micronutrient. Lawn fertilizers generally contain no significant amounts of zinc. In the environment, zinc typically remains in the upper layers bound to soil particles. Concentrations of zinc in sandy soil particles are about 200 times higher than in the water between the soil particles, and concentration ratios are even higher (over 1,000) in both loam and clay soil (Argonne National Laboratory, 2005).

From automobiles and other vehicles, brake wear is a significant source of copper and other metals, but not a significant source of zinc, which is not present at appreciable levels in brake linings. Vehicular exhaust is known to contain zinc, but literature does not point to this as a significant source of zinc to the environment.

2. Facility Source Inventories

Introduction

Inventories were conducted at 28 industrial facilities under the ISGP to identify possible sources of zinc in their stormwater discharges.

Source inventories were carried out in sufficient depth and accuracy to develop a picture of sources of zinc on a survey-wide basis. However, the inventories were not conducted in enough depth or with sufficient confirmation to be definitive for individual facilities.

Study Design

Twenty-eight industrial facilities in the Kent, Washington vicinity were selected for inventories. The 28 facilities all have provided Ecology with self-reported data. With two exceptions, all have reported at least two data points (from two quarters of sampling). The sample population for this study includes most qualifying facilities in the Kent area.

A form developed from the literature search listed possible sources of zinc to be checked at each facility (Appendix B). Supplementary notes in the field included descriptions of specific sources and relative areas of roofs, parking areas, loading docks, and grounds. Information was noted concerning monitoring sites selected by facility personnel as well as monitoring procedures used.

Inventory Results: Sources of Zinc at Industrial Facilities

For the most part, inventories identified significant zinc sources to be, as expected, galvanized materials on roofs and materials released from vehicles on the grounds. This is an important finding because, in the planning stages of this study, it was believed the cause of high zinc concentrations in self-monitoring data might be sources that are unusual or particular to industrial facilities.

Summaries of each of the 28 inventories appear in Appendix C. Each summary includes self-reported data, an evaluation of the appropriateness of sampling and reporting, and a rating of the level of inventoried zinc sources on roofs, and from parking areas, loading docks, and grounds. These sources were rated at each facility as high, medium, or low relative to the extent of sources found at all facilities.

Table 1 shows common sources of zinc in stormwater discharge from industrial facilities.

Table 1. Common Sources of Zinc in Stormwater Runoff from Industrial Facilities

Facility Area	Facility Source	Specific Source
Roofs	Galvanized HVAC, ducts, ventilation fans, turbines, etc. Galvanized downspouts	Galvanized metal
Parking Areas	Automobiles	Motor oil, tire particles
Loading Docks	Trucks, Forklifts	Motor oil, tire particles. Hydraulic fluid, motor oil, tire dust
Grounds	Truck/trailer or bus parking Material storage	Galvanized metals, materials storage, and vehicles (as above)

For all 28 facilities surveyed, industrial processes were located indoors, leaving roofs and ground surfaces as potential sources of zinc in runoff.

Table 2 identifies major sources for each inventoried facility. The facilities shown in Table 2 are ranked by the mean of the facilities' self-reported data. Facility 1 reported the lowest mean concentration of total zinc, facility 28 the highest.

For purposes of comparison, the 28 facilities are grouped as having high or low reported zinc concentrations in stormwater discharges. Those facilities grouped as "low" had no value as high as the action level of 372 µg/L and a mean concentration of zinc in runoff lower than 200 µg/L. These criteria were selected so as to divide the 28 facilities evenly into the two groups.

Table 2 identifies, for each facility inventoried, the areas with medium to high levels of zinc sources relative to areas of all facilities. The extent of sources found through inventories (shown by x's) is essentially the same for facilities reporting low and high zinc concentrations. The importance of roof or grounds as sources of zinc to stormwater runoff is distributed roughly evenly among facilities, with no correlation with high or low levels of self-reported zinc concentrations.

While roofs and grounds were the principal sources of zinc, facilities with specific sources included:

- 7 with forklifts, one bulldozer.
- 3 with high-density truck storage, one with bus storage.
- 1 with an electric utility substation and towers on the grounds with large galvanized areas.
- 1 with a galvanized metal roof.

Table 2. Inventoried Sources of Zinc in Stormwater Runoff by Facility

Facility Number	Mean Zinc (TR)	M - H Roof	M - H Grounds	Specific Sources
Reporting Low Zinc Concentrations				
1	41	--	--	Small area of galv on roof. Large areas of unused grounds.
2	67	x	x	Galv on roof; galv garage door (sheltered from rain); 2 cranes (hydraulics)
3	76		x	Forklifts (hydraulics); galvanized downspouts
4	82		x	Forklifts (hydraulics)
5	87	x	x	Galvanized blower covers on roof; parking lot swept once per month
6	99		x	Galvanized storm sewer (older, well coated with organic material)
7	103		x	Auto wrecking yard on unpaved grounds
8	105*		x	Forklifts (Means shown is after forklifts fixed, maintained one year ago)
9	106		x	No galvanized on roof
10	122	x	x	Galvanized stack
11	125		x	Galvanized electric transformer and towers, 200 ft chain-link mid-property
12	127	x	x	Very large area of galvanized on roof, galvanized stack on ground
13	149		x	Galvanized storm sewer, well coated with organic material
14	173	x	x	Forklifts, hydraulic truck lift
Reporting High Zinc Concentrations				
15	219		x	Heavy truck traffic, forklifts, galvanized storm sewer
16	225		x	Heavy forklift traffic
17	240	x	x	No unusual sources
18	274	x	x	Galvanized ductwork on roof
19	276		x	Bulldozer on site
20	282		x	Large number of buses parked on grounds
21	289	x	x	Galvanized ductwork on one roof
22	290	x	x	Zinc-rich paint on roof ductwork (to protect aged galvanized surfaces)
23	311		x	Heavy truck traffic and parking, tight space; chain-link in drainage area.
24	332		x	Heavy truck traffic, tight turning space; galvanized blower covers on roof
25	373	x		Large number of galvanized roof turbines
26	455	x	x	Entire roof galvanized
27	463		x	No large sources identified, except possibly landscape fertilizer
28	629		x	Continuous forklift traffic

TR – total recoverable analysis (also equivalent to total analysis)
M - H – facilities rated medium or high for relative level of zinc sources present (Appendix C)
*Data from most recent four quarters; forklifts repaired to eliminate hydraulic leaks and facility area cleaned up.

Facilities with large and active loading docks/grounds may find these areas to be sources of higher concentrations of zinc in runoff. For example, facility #s 16, 23, and 24 had high truck and/or forklift traffic and relatively high self-reported zinc concentrations (Table 2). (Facility 16, with three forklifts operating in a small area, would be ranked 24th of 28 if the facility's most recent self-reported results, after cleanup, were excluded.)

Galvanized chain-link fences were found at many facilities. Though they have relatively large surface areas of galvanized metal, in most cases chain-link fences were considered not to contribute substantially to zinc in facility runoff. Fences were usually around facility perimeters and draining off site. In some cases, perimeter fences drained across a vegetated strip before reaching paved surfaces. The fence at mid-property of one facility was vinyl coated. Such fences are known to contribute essentially no zinc to runoff.

3. Facility Monitoring

Introduction

Monitoring at two facilities was conducted to evaluate potential sources of zinc from typical areas within a facility. This monitoring was conducted in part to support the assessment of source areas in Part 2 of this study.

One facility was selected for overall facility monitoring of roof, parking, and loading dock area runoff, as well as overall stormwater discharge from the site. Monitoring at the second facility focused on roof runoff only, with one roof supporting a medium to high relative area of galvanized materials, the other with no galvanized materials.

The selection of areas to monitor was informed by studies by Pitt et al (1995, 2000) in which roofs, parking areas, storage areas, streets, loading docks, vehicle service areas, and landscaped areas were sampled. Of these, the areas with the highest levels of metals in runoff were roofs, parking areas, and loading docks.

Overall Facility Monitoring

One facility (#18 in Appendix C) was chosen for comprehensive sampling. The facility includes areas common to the facilities in this study: roof, parking, and loading dock. The facility, like the majority of those surveyed in this study, is a light industry with all industrial processes located indoors. As shown in Appendix C, the facility's inventoried zinc sources, relative to other facilities were as follows:

- Roof, medium to high
- Parking lot, medium
- Loading dock, low to medium

The facility is typical of those with no sources apparent other than roof, parking, and loading dock areas. This facility differed from some in having a small loading dock of only four truck spaces, no forklifts, and a low intensity of truck traffic. Facilities with large and active loading dock/grounds areas may find these areas to be sources of higher concentrations of zinc in runoff.

Facility #18 had approximately 40% of exposed facility area as roof, the other 60% parking, loading dock, and paved grounds. A roof area comparable to or somewhat less than the non-roof area is typical of the facilities in this study.

In a rank-ordered list of mean zinc concentrations from self-reported data, the facility was in the mid to upper range: 18th of 28.

Roof, parking, and loading dock areas were monitored at Facility #18 to gain a sense of the extent to which each area contributes zinc to runoff. Overall stormwater discharge from the facility was also sampled at the sampling site used by facility personnel for self-monitoring.

Roof Monitoring Only

Roofs at eleven of the 28 facilities in the study are grouped as supporting medium to high areas of galvanized materials, as shown in Table 2. The second facility chosen for monitoring (#21 in Appendix C) had two nearly identical roofs, though one supported a moderate area of galvanized surfaces and the other, none. The principal galvanized surface on the first roof was ductwork. Runoff from the two roofs was monitored to gain a sense of the extent to which galvanized materials on roofs contributes to zinc in stormwater runoff.

The roofs of this facility were listed in Table 2 as having overall medium to high sources of zinc (galvanized materials), as were 10 other facilities of the 28 surveyed.

The roofs were flat, as were those of most of the 28 facilities in this study. (The peaked roofs found at some facilities were of paint-coated metal, generally with no galvanized materials on them.) Samples of runoff from the roofs with and without galvanized materials on them were collected from downspout discharges at ground level. In addition, an effort was made to monitor roof runoff above and below one galvanized metal downspout to explore its potential as a source of zinc.

Study Design

Parameters monitored at both facilities (#18 and #21) were:

- Zinc, total recoverable (TR)
- Zinc, dissolved (diss)
- Hardness
- Total suspended solids (TSS)

Zinc was analyzed as total recoverable (total), the form of zinc self-monitored and reported by each facility under the ISGP. The benchmarks and action levels of the ISGP are for total zinc. Zinc was also analyzed as dissolved zinc. Receiving water quality criteria are for dissolved zinc. A source can be characterized in terms of the relationship between these two forms. Hardness was monitored because it is a parameter on which water quality criteria are dependent for some metals including zinc. Total suspended solids (TSS) represents the concentration of suspended materials in a sample.

Monitoring was to take place under conditions consistent with those required by the ISGP:

- Each storm event must be preceded by at least 24 hours of no measurable precipitation.
- Each storm event must be an intensity of at least 0.1 inches of rain per 24-hour period.
- All grab samples must be taken within the first hour after discharge begins.

Monitoring studies of stormwater runoff quality most often are based on sampling throughout a storm event as composite or sequential samples. This survey study was limited to grab sampling, as conducted by most facilities. A short time period and low flow rate of runoff typical of short springtime storms would have made composite sampling difficult.

The usefulness of grab samples in representing stormwater quality is limited because stormwater varies considerably between and within storms. A small number of grab samples, as in this study, cannot be used to develop a complete characterization of stormwater runoff. However, because zinc concentrations encountered varied widely, even grab samples often appeared to show differences between facilities and sources. Also, the utility of data depends not only on how extensive they are, but also on the extent of existing data. Little has been published about sources of zinc in sub-areas of industrial facilities. The data generated in this study provide a needed sketch of sources of zinc to runoff within industrial facilities.

Grab samples at Facility #18 (*Overall Facility Monitoring*) were taken during storm events on five days during March and April, 2005. Sampling at Facility #21 (*Roof Monitoring Only*) took place during two days in April. Sampling in spring offers weather providing longer periods of preceding dry weather and more opportunities for worst-case sampling than may be encountered during the winter, wet season.

Sample Collection

Field personnel wore nitrile, powder free gloves, to prevent contamination of the samples. Each sample was given an ID number, tagged, and kept cool at 4°C. Chain-of-custody procedures were observed, and samples were delivered to the laboratory within allowable holding times for each parameter.

A summary of parameters, collection containers, sample preservation, and holding times for both facilities appears in Table 3.

Table 3. Sample size, Container, Preservation, and Holding Time by Parameter.

Parameter	Sample Size	Container	Preservation	Holding Time
Zinc (TR)	500 mL	1 L HDPE bottle	HNO_3 to pH<2	6 months
Zinc (dissolved)	500 mL	1 L HDPE bottle	HNO_3 to pH<2	6 months
Hardness	100 mL	100 mL	H_2SO_4 to pH<2	6 months
TSS	1000 mL	1000 mL w/m poly	Cool to 4°C	7 days

Overall Facility Monitoring

Overall facility monitoring samples from Facility #18 were taken as single grabs during storm events on five separate days. Samples of roof runoff at the facility were collected from pooled areas on the roof of the facility, near inlets to downspouts. The roof was sampled with pans fashioned of aluminum foil. Runoff was skimmed from pools of shallow water (one or two inches deep), near downspouts where water was draining. The efficacy of sampling with aluminum foil was verified by analyzing blanks consisting of distilled water collected in a foil pan and then transferred to a collection bottle (see *Data Quality* section of this report).

Samples from the parking area and loading dock were collected directly into sample containers. Sampling containers were held under the lip of stormwater catch basins, in order to sample sheet runoff from the parking area and loading dock. Two portions of the roof were sampled: one with a modified bitumen roof coated with aluminized paint, the other a newer portion with a surface of PVC.

Final stormwater discharge was sampled by attaching a sampling bottle to a pole and lowering it into a catch basin. Stormwater flowing at the bottom of the basin included combined inflows from multiple catch basins connected through storm sewer.

Roof Monitoring Only

Samples of roof runoff only, from Facility # 21, were taken as grabs of downspout discharge from each of the two roofs during two separate storm events. Two samples at different times of day were collected during both storm events.

To test for contributions of zinc from a galvanized metal downspout, runoff from the roof without galvanized materials was sampled at both ends of the downspout, above on the roof and below at ground level.

The roof on which there were no galvanized materials was sampled with pans fashioned of aluminum foil. Runoff was skimmed from pools of shallow water near the top of the downspout below which samples were taken.

Analytical Methods

Analytical methods are shown in Table 4.

Table 4. Analytical Methods

Analyte	Sample Matrix	Sample Prep Method	Analytical Method	Method Reporting Limit
TSS	water	--	Std Method 2540	1 mg/L
Hardness	water	--	EPA 200.7	1 mg/L
Turbidity	water	--	Std Method 2130	0.5 NTU
Zinc (TR)	water	Digested with mixture of nitric and hydrochloric acids	EPA 200.8	5 µg/L
Zinc (dissolved)	water	Field filtered	EPA 200.8	1 µg/L

TSS – total suspended solids
TR – total recoverable

Data Quality

Laboratory duplicates and field replicates allow for a determination of analytical and sampling error. Appendix A shows duplicates and replicates precision data. Blank samples of deionized water used to assess any contamination of samples during collection or transfer to containers also appear in Appendix A.

Relative percent difference (RPD) is an indicator of variability obtained by dividing the difference between two values by their mean. All but one laboratory duplicate for TSS had RPDs below 20% or within 1 mg/L of sample results. A sample and laboratory duplicate sample of roof runoff had an RPD of 56%.

Field replicate samples for TSS showed unusually high RPDs, as high as 182%. Roof sampling by skimming water from shallow pools tended to stir up large settled particles from roof surfaces included in many of the samples. Other samples were obtained with little disturbance, introducing considerable variability in TSS results. It was also difficult to sample from paved areas without entraining settled solids. This points to a difficulty in sampling runoff from sub-areas within some industrial facilities, or, in some cases, of the overall stormwater discharges themselves. Visual observations from roofs showed little or no visible solids entering downspouts. Precipitation was light to moderate in intensity during this study. It may be that heavier rains would dislodge large particles to become part of the roof runoff.

For total recoverable zinc, field replicates had relative RPDs as high as 45% for roof and 58% for parking area sampling sites. These RPDs show less accuracy than the Quality Assurance (QA) Project Plan data quality goal of 24% of true value. Results showed similar RPDs for dissolved zinc as TR zinc samples. Even so, results were adequate for the study purpose of assessing approximate relative concentrations from different source areas.

Blank results of 5.0 µg/L for TR zinc, and 2.9 µg/L for dissolved zinc, coincided with the lowest concentrations of interest of 5.0 and 2.9 µg/L specified in the QA Project Plan. All reporting limits were well below benchmark levels set in the ISGP.

Results and Discussion

The following discussions of sampling criteria and the procedure used to report central tendency of data and criteria apply both to *Overall Facility Monitoring* and *Roof Monitoring Only*.

It is the requirement of the ISGP that samples be taken during the first hour of discharge preceded by at least 24 hours of no greater than trace precipitation. A permit modification effective January 14, 2005 allows monitoring if either of these or other sample collection criteria cannot be met, with the reason for an exception reported to Ecology. Before that time, facilities often did not report data for some quarters, notifying Ecology that there were no qualifying days to sample.

All sampling was conducted on the first day of rainfall after at least one day of no significant precipitation. Sampling on March 26 and 29 and April 15 took place during the first three hours of stormwater discharge from each facility. Sampling on April 7 and 29 took place after moderate to heavy rainfall was already in progress. These exceptions to ISGP monitoring requirements were in part the result of logistical difficulties of sampling at two locations and the difficulty of determining first hour of discharge from a base of operations some 50 miles distant. As the principal aim of monitoring was to measure relative differences between sources within a facility, these exceptions were considered acceptable.

The mean rather than median was used to represent the central tendency of study data. The mean is considered a more reliable statistic than median for small data sets (n=6 or lower for this study). Box-and-whisker plots of results are, by necessity, based on median values.

Overall Facility Monitoring

Results of analyses of samples from roofs, parking areas, loading docks, and overall discharge at Facility #18 are shown in Table 5. The mean values presented in Table 5 are from three sampling dates only: April 7, 15, and 29, 2005. All areas were sampled on these dates. Results are shown as a box-and-whisker plot with median, high, and low quartiles, and minimum and maximum values.

Table 5 shows that three of the five days of discharge had TR zinc concentrations greater than the ISGP benchmark of 117 µg/L.

Figure 1 shows that the concentration of zinc in the facility's overall discharge is between the relatively low zinc concentrations of the loading dock and parking areas and the higher zinc concentrations of the roof surfaces. That neither roof nor grounds overshadowed the other as determining overall stormwater discharge concentration lends support to comparing roof vs. grounds on an even-footing in Part 2, *Facility Source Inventories*, of this report.

The stormwater discharge results in Table 5 are similar to those from self-monitoring conducted during previous quarters (102, 228, 136, 100, and 131 µg/L of this study versus 130; 360; 250; 240; 390 µg/L self-reported), with the exception of the two highest self-reported results (390 and 360 µg/L). These high results were both found during the summer quarter (July-September) of 2003 and 2004 respectively. Summer storms tend to come after long periods of dry weather, during which pollutants can build up on outdoor surfaces. This study, conducted in the spring, may have missed worst-case conditions, and so under-represented maximum zinc concentrations. Comparisons of relative results between sources and facilities, however, can be expected to hold.

Samples of final stormwater discharge were drawn from the pooled water in the final catch basin at the edge of facility property, both by the facility for self-monitoring and in this monitoring study. The pooled water provided conditions for solid particles to settle out, as it did not appear to be flowing. This is consistent with the finding that the dissolved zinc fraction comprised most of the total zinc in the discharge sample (Table 5, Figure 1).

Table 5. Results from Monitoring of Facility Roof, Parking, and Loading Dock Areas, March and April 2005

Sampling Site	Lab Log #	Sampling Date	Time	Zinc			Hardness mg/L	TSS mg/L
				TR µg/L	Dissolved µg/L	Dissolved %		
PARKG1	5138472	3/26	700	124	23.9	19	3	30
PARKG2	5138474	3/26	900	96.3	20.9	22	2.7	37
DISCH1	5138471	3/26	700	104	109	100	2.4	6
DISCH2	5138473	3/26	900	100	81.4	81	1.8	7
ALROOF	5138478	3/29	1415	371	261	70	2.9	50 J
PVCROOF	5138477	3/29	1420	135	120	89	2.4	33 J
PARKG	5138476	3/29	1435	284	141	50	11.6	73 J
DISCH	5138475	3/29	1445	228	203	89	5.4	12 J
ALROOF	5144043	4/7	1115	139	133	96	1.6	26
PVCROOF	5144042	4/7	1100	106	75.3	71	2.9	22
PARKG	5144041	4/7	1155	40	27.9	70	2.5	16
LOADG	5144040	4/7	1140	85.1	45.5	53	5.5	21
DISCH	5144044	4/7	1210	136	128	94	2.7	7
ALROOF	5154112	4/15	1405	150	123	82	1.7	22 J
PVCROOF	5154111	4/15	1345	72.1	77.3	100	0.9	7 J
PARKG	5154110	4/15	1435	57.3	38.4	67	2.7	30 J
LOADG	5154109	4/15	1455	118	71.2	60		
DISCH	5154113	4/15	1445	100	103	100	2.7	6 J
ALROOF	5174139	4/29	1220	374 J	334	89	0.7	4
PVCROOF	5174138	4/29	1215	192 J	179	93	1.1	5
PARKG	5174137	4/29	1230	46.5 J	25.1	54	1.4	11
LOADG	5174136	4/29	1240	74.4 J	49.4	66	2.8	16
DISCH	5174140	4/29	1250	131 J	118	90	2.2	3
Mean Values*								
ALROOF				221	197	89		
PVCROOF				123	111	90		
PARKG				48	30	63		
LOADG				93	55	59		
DISCH				122	116	95		

ALROOF – Modified bitumen (asphalt) roof with aluminized paint coating
PVCROOF – Portion of roof with PVC surface
PARKG – parking lot
LOADG – loading dock
DISCH – combined stormwater discharge from the entire facility (the site for self-reporting)

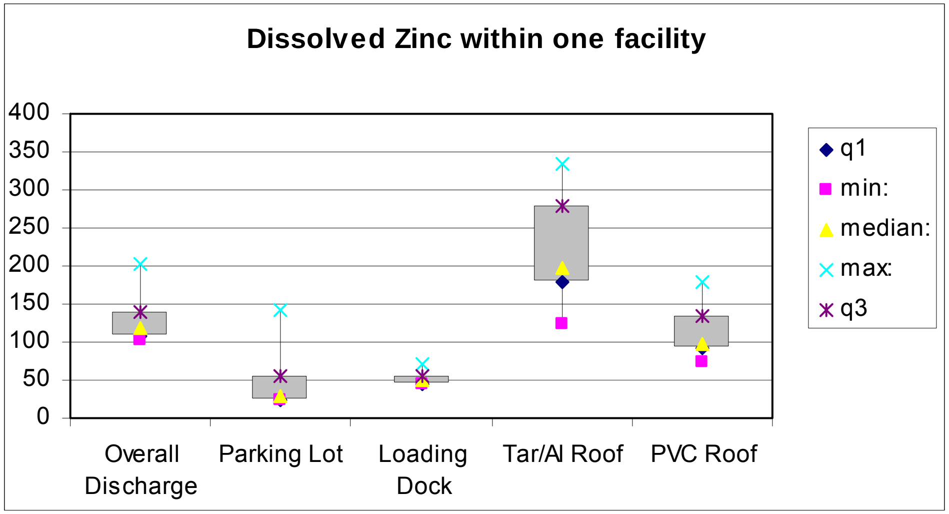
J - estimated value (heterogeneous mixture)

* For samples on 4/7, 4/15, and 4/29 - dates on which all areas were sampled.

As discussed in the *Data Quality* section of this report, TSS sample results were unreliable as a result of difficulties grabbing samples without stirring up settled solids.

Table 5 shows mean total recoverable concentrations of zinc from the parking and loading dock areas of 48 and 93 µg/L, respectively. Mean dissolved zinc concentrations are 30 and 55 µg/L, respectively. While these results are not definitive, they may reflect heavier vehicle use at the loading dock area compared with that of parking areas where employees typically come and go once daily. Large trucks may leak larger amounts of oil than automobiles, and their tires may release more rubber as they make tight turns. Facilities with forklifts and higher volumes of truck traffic than those of the monitored facility may show higher zinc concentrations in runoff from loading dock and grounds areas.

As Table 5 and Figure 1 show, zinc in roof runoff is mostly or all in the dissolved fraction. This is as expected, assuming zinc released from galvanized surfaces is in dissolved form. Parking areas and loading docks showed dissolved zinc being a portion of total recoverable (total) zinc. For the three days of loading dock sampling, 47%, 40%, and 34% of zinc were found in other than dissolved form (53%, 60%, and 66%, respectively, in dissolved form). The non-dissolved fractions at two Tree Top facility loading areas with tire dust evident were somewhat higher: 53% and 51% (Davis, 2005b). It may be that tire particles can be the major source of zinc particles (the portion of zinc not dissolved) in loading dock runoff samples. Further investigation would be needed to determine this.



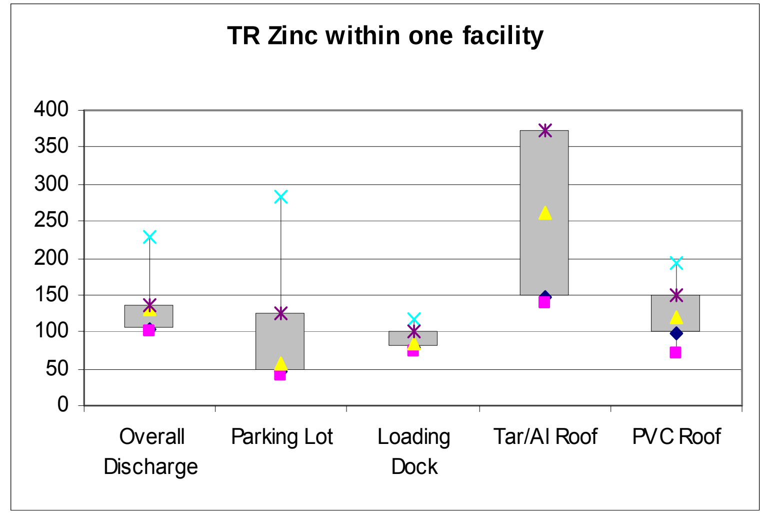


Figure 1. Total and Dissolved Zinc Concentrations – Overall Facility Monitoring.

Roof Monitoring Only

Results from Facility #21, the facility for which samples were taken from roof and downspouts, are shown in Table 6. Downspout samples from the roof with galvanized materials showed much higher zinc concentrations than those from the roof without galvanized materials. A mean of 337 µg/L was found for the roof with galvanized materials compared with a mean of 105 µg/L for the roof without. Self-monitoring of the two roofs showed a similar difference between runoff from the two roofs, with means of 528 and 49 µg/L.

Table 6. Results from Monitoring of Roofs With/Without Galvanized Materials, April 2005.

Sampling Site	Lab Log #	Sampling Date	Time	Zinc TR µg/L	Zinc Dissolved µg/L	Zinc Dissolved %	Hardness mg/L	TSS mg/L
DWNSPGAL	154106	4/15	1230	433	473	100	3.61	4 J
DWNSP	154105	4/15	1210	146	149	100	8.72	4 J
(ROOF)	154107	4/15	1200	119	78.8	66	8.68	23 J
DWNSPGAL	154115	4/15	1620	217	241	100	--	2 J
DWNSP	154114	4/15	1540	61	62.1	100	--	2 J
(ROOF)	154116	4/15	1600	66.7	73.5	100	--	4 J
DWNSPGAL	174131	4/29	1010	391 J	384	98 est.	2.1	2
DWNSP	174130	4/29	955	167 J	156	93 est.	7.66	3
DWNSPGAL	174143	4/29	1420	308 J	287	93 est.	1.8	1 U
DWNSP	174142	4/29	1340	47 J	48.2	100 est.	2.2	1
(ROOF)	174141	4/29	1410	69.0	51.5	74	2.1	16
Mean Values*:								
DWNSPGAL				337	346	100		
DWNSP				105	103	100		
(ROOF)				85	68	80		

DWNSPGAL - Downspout from roof with galvanized surfaces.
DWNSP - Downspout from roof with no galvanized surfaces.
ROOF - Top of roof above downspout to compare with DWNSP

J - estimated value (heterogeneous mixture)
U - The analyte was not detected at or above the reported result.

Total recoverable zinc results of all samples from the downspout of the roof with galvanized ductwork (433, 217, 391 est., and 308µg/L est.) were above the 117 µg/L benchmark. Two of the four samples showed results above the 372 µg/L action level.

For the roof without galvanized materials, it was thought that zinc concentrations at the bottom of the downspout might be higher than those on the roof near the top of the downspout. The limited grab sampling results were not adequate to determine this, but values were similar in both locations. This suggests the impact of galvanized downspouts on zinc concentrations overall may, at least in some cases, not be great.

In most instances, dissolved metals concentrations from a sample are equal to or lower than total recoverable concentrations. Some of the sampling locations in Table 6 show higher dissolved than total recoverable zinc concentrations. However, the results for both forms of zinc are within laboratory standards, and it can be assumed that in these cases approximately 100% of total recoverable zinc is in the dissolved form.

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4. Usefulness of Self-Monitoring Data

Over 1,000 industries in Washington State with permits under the Industrial Stormwater General Permit (ISGP) are required to provide stormwater discharge data to the Department of Ecology (Ecology) once per quarter. In most cases, the data submitted is from grab samples. In the field of stormwater data collection, sampling more extensive than individual grab samples is often needed to characterize runoff at a facility. Applying grab data in a more general way, however, may serve to provide general information for an aggregate of facilities. This is the basis for the following analysis of self-reported data to Ecology from the 28 facilities surveyed in this study.

While data from small numbers of grab samples of stormwater runoff are not adequate to provide a quantified representation of pollutants at a facility, the data may still provide clues for on-the-ground inspections. Grab sample data from individual industrial facilities may be of use as a tentative indicator of the extent of pollutant sources or the efficacy of self-monitoring procedures. Self-reported zinc concentrations and more detailed assessment information for each of the 28 facilities appear in Appendix C.

Self-Reported Data and Their Validity, by Facility

Table 7 shows self-reported total zinc data from the 28 inventoried facilities. The facilities have been rank-ordered by mean, and assigned facility numbers by rank.

Table 8 summarizes, from information in Appendix C, indications of the efficacy of self-reporting at the 28 facilities, listed in order of self-reported zinc concentrations from lowest to highest. Whether self-sampling/reporting at each facility appears to have introduced error or bias is indicated in the table, as well as the direction of such errors or biases, to under-report or over-report zinc concentrations in stormwater discharges. Causes of under-reporting are listed.

At seven of the 14 facilities with the lowest self-reported values, it appeared that sampling or reporting was done in a way that misrepresented actual values or introduced errors or biases, all in the direction of under-reporting pollutant concentrations. By contrast, in the list of the 14 facilities with the highest self-reported values, sampling and reporting data from all facilities except one appeared to be valid.

Table 7. Self-reported Data, Means, and Rank-ordering of Facilities by Mean Zinc Concentrations, 2003 – 2005.

Facility #	Self-reported values (total zinc, µg/L)						Mean
1	22	24	58	61			41
2	120	20	39	110	44		67
3	223	2.09	3.4				76
4	50	130	100	90	50	70	82
5	100	120	40				87
6	77	63	94	160			99
7	58	28	118	104	205		103
8	89	25	280	25			105
9	106						106
10	49	169	224	44			122
11	199	52					125
12	163	250	61	174	81	35	127
13	102	197					149
14	170	70	140	310			173
15	180	165	167	374	208		219
16	430	200	46				225
17	556	212	184	146	102		240
18	130	360	250	240	390		274
19	684	162	192	67			276
20	195	318	266	239	213	462	282
21	43	567	490	55			289
22	190	210	484	477	121	256	290
23	239	399	604	119	194		311
24	619	180	347	181			332
25	680	170	300	340			373
26	700	338	396	385			455
27	463						463
28	1500	234	152				629

Table 8. Evaluation of the Validity of Self-Monitoring/Reporting by Facility

Facility Number	Mean Zinc (Total)	M - H Roof	M - H parking loading grounds	Does self-sampling/ reporting appear to misrepresent or enter error or bias?	Expected tendency to over/under report	Description of self-reporting factor appearing to introduce error or bias
Reporting Low Zinc Concentrations						
1	41	--	--	No	--	
2	67	x	x	Yes	Under	Run-on from wooded hillside
3	76		x	Yes	Under	Very low zinc #s reported in error
4	82		x	Yes	Under	Samples not of runoff
5	87	x	x	Yes	Under	Reported only lowest day of 5
6	99		x	No	--	
7	103		x	No	--	
8	105*		x	No	--	
9	106		x	No	--	
10	122	x	x	No	--	
11	125		x	Yes	Under	Of 3 sample sites, picked lowest #s
12	127	x	x	Yes	Under	Parking area only was sampled
13	149		x	No	--	
14	173	x	x	Yes	Under	Parking area only was sampled
Reporting High Zinc Concentrations						
15	219		x	No	--	
16	225		x	No	--	
17	240	x	x	No	--	
18	274	x	x	No	--	
19	276		x	No	--	
20	282		x	No	--	
21	289	x	x	Yes	Under	First day of rain is avoided
22	290	x	x	No	--	
23	311		x	No	--	
24	332		x	No	--	
25	373	x		No	--	
26	455	x	x	No	--	
27	463		x	No	--	
28	629		x	No	--	

M - H – facilities rated medium or high for relative level of zinc sources present (Appendix C)
* Data from most recent four quarters, with forklifts repaired to eliminate hydraulic leaks and facility area cleaned up.

Case Studies

Following are brief descriptions of how clues offered by self-reporting data corresponded to conclusions of source inventories in this study for many of the 28 facilities surveyed. Although data were from only a limited number of grab samples, causes of low self-monitoring results are evident. Self-reported zinc concentrations and more detailed assessment information for each facility appear in Appendix C.

The label “UNDER” identifies facilities that provide data with an expected tendency to under-report zinc concentrations. The label “VALID” identifies facilities that appear to have sampled and reported without error or bias.

Facilities reporting low zinc concentrations in runoff (11 of the 14 lowest):

- Facility 1: VALID

  The facility self-reported very low zinc concentrations in the final stormwater discharged. This was consistent with the source inventory that found a large facility with few sources and with the observation of extensive areas of pavement and compacted soil surfaces rarely used. In addition, the runoff was discharged and sampled at the downstream end of a vegetated pond serving as a best management practice (BMP).

- Facility 2: UNDER

  The inventory showed moderate-to-high areas of galvanized materials on the roof and moderate sources of zinc on the grounds. Only facilities with grounds largely free of potential sources were found in this study to report concentrations as low as this facility’s three lowest values (20, 39, 44 µg/L). Self-reported data may be the result of stormwater running onto the facility from a steep wooded hillside larger than and above the facility. The hill slopes down to a curb along the side of the facility.

- Facility 3: UNDER

  Self-monitoring from this facility included unreasonably low zinc concentrations, an evident error in laboratory or facility reporting. Two reported zinc concentrations are obvious outliers, a factor of 10 below zinc concentrations found elsewhere in this study.

- Facility 4: UNDER

  The downstream end of grassy swale is the final stormwater discharge point for the facility. Sample point for self-reporting is in a manhole vault next to a grassy swale. Facility personnel report that the water never rises in the swale sufficiently to flow through the pipe to the vault.

- Facility 5: UNDER

  Low reported zinc concentrations appeared inconsistent with the medium-to-high inventory assessment of roof and loading dock sources. The data self-reported to Ecology were found to be from only the lowest of five quarters (five days) of the facility's data.

- Facility 6: VALID

  The inventory found a large number of trucks in a relatively small area. Low zinc concentrations (77, 63, 94, 160 µg/L) are well below expected for a typical facility with high-density truck parking. While the possibility was not explored in this study, the effectiveness of catch-basin inserts as BMPs as well as the practice of sweeping pavement surfaces on a twice-monthly schedule may be responsible for the low zinc values.

- Facility 7: VALID

  Monitoring discharge from the downstream end of a grassy swale (BMP) may be responsible for low self-reported zinc concentrations. Monitoring at the facility takes place "after it has rained for a while," rather than during the first hour of discharge, as specified by the ISGP. Anecdotal experience suggests that such late sampling may not be unusual among facilities. The modified ISGP permit of December 2004 allows time of sampling as an exception but only if necessary and documented.

- Facility 8: VALID

  Recent self-reports showed a large reduction in zinc concentrations. The lower numbers are consistent with personnel reporting repair and maintenance of forklifts. The forklifts had been leaking hydraulic fluid to the point that a slip/trip hazard had been created. Sampling procedures at the facility are said to have not changed.

- Facility 11: UNDER

  Low self-reported zinc concentrations appeared inconsistent with moderate-to-high truck traffic and large area of galvanized materials on the grounds (electric power substation, galvanized towers). Permittee reported lowest result of three sample locations. The ISGP requires that the highest of multiple locations be reported.

- Facility 12: UNDER

  The site inventory found a large area of galvanized materials on the roof and grounds. The loading dock area has a surface less clean than typical. It appeared evident that low self-reporting numbers were not indicative. The runoff area sampled was found to be limited to a small portion of the facility's parking area, excluding roof and loading dock areas.

- Facility 14: UNDER

  The reported zinc concentrations appeared inconsistent with relatively heavy truck and forklift traffic and the large area of galvanized materials on the roof. The runoff sampled was found to be limited to that from the employee parking area.

Facilities reporting high zinc concentrations in runoff (3 of the 14 highest):

- Facility 16: VALID

  Excluding data from the most recently reported quarter, the facility stormwater discharge had a mean of 315 µg/L total zinc and would be ranked 24th of 28. The most recent self-report showed a considerably lower zinc concentration than previous data, indicating a possible change in sources at the facility or sampling. Personnel report cleaning up the loading area after several years of accumulating wood chips, perhaps absorbing motor oil and hydraulic fluid.

- Facility 21: UNDER

  Roof area comprises most of the facility's area, making the selection of roofs as sampling sites appropriate. Personnel systematically exclude the first day of rainfall at this facility; this is contrary to the requirement of the ISGP that samples be taken during the first hour of stormwater runoff. If, as is often assumed, initial runoff during a storm has the highest concentration of pollutants, this facility has tended to under-report zinc concentrations.

  Self-reported data showed an unusual pattern of alternating high and low zinc concentrations, the high results being 10x higher. The facility alternates sampling between its two roofs. An inspection of the roofs confirmed the expectation that one roof would have a large area of galvanized materials, the other essentially none. The pattern of self-reported data pointed to this facility for selection as the site for the "Roof Runoff Only" monitoring for this study.

- Facility 26: VALID

  The facility inventory found unusually clean grounds, with large areas unoccupied. The self-reported high zinc concentrations indicated there may have been a major source of zinc. This was confirmed during the final step of the inventory, with the finding that loading dock roof and shop roof were of galvanized metal – the only galvanized roofs of the study.

The findings of these case studies lead to three general observations that also may be true of other pollutants:

1. It may be that many facilities report lower than actual concentrations of zinc, with data collected or reported in such a way as to introduce bias or error.
2. Error or bias in self-reported data appears in all cases to be in the direction of under-reporting zinc concentrations.
3. Zinc concentrations in stormwater discharges from industrial facilities in this study overall, and perhaps statewide, may be higher than self-monitoring data indicate.

The following generalities about self-reported data may, in part, guide the assessment of possible major sources of zinc at a facility on a screening-level basis. A definitive determination of sources and their extent would require a more thorough investigation, with the possible inclusion of sub-area sampling.

- If high zinc concentrations are reported, even for a limited number of grab samples, a considerable source or sources of the pollutant may be indicated.
- If low concentrations are reported, one of the following may be indicated:
  - Pollutant sources are low.
  - Effective BMPs are used at the facility.
  - Faults with sampling or reporting have caused pollutant concentrations in stormwater discharge to be under-reported.

Conclusions

The principal sources of zinc identified as contributing to stormwater runoff from industrial facilities are as follows:

- Galvanized surfaces on roofs (e.g., HVAC, ductwork, ventilator covers).
- Motor oil, hydraulic fluid, and tire dust on parking, loading dock, and grounds surfaces. Cars, trucks, and in some cases forklifts are the presumed sources of these materials.

If the 28 facilities inventoried are typical, most facilities under the ISGP are providing valid self-data. Twenty of the 28 appeared to have sampled and reported zinc concentration data without error or bias.

Facilities providing data that are not indicative of actual concentrations are most often those reporting low concentrations of zinc. Zinc concentrations in stormwater discharged from facilities in this study, and perhaps statewide, are likely higher than self-monitoring data indicate. However, many facilities reporting low concentrations appear to be doing so properly. These facilities show few sources of zinc and/or employ effective best management practices (BMPs) to reduce zinc concentrations discharged.

Although data are far from sufficient to be conclusive, the effectiveness of source-control BMPs appears to correspond to relatively low zinc concentrations in stormwater discharges from two of the 28 inventoried facilities (Facilities 1 and 6).

A monitoring study of two facilities indicates that both roofs and grounds may contribute substantially to zinc in industrial stormwater discharges. Runoff concentrations of zinc can be high from roofs with considerable areas of galvanized surfaces; runoff from roofs without galvanized materials generally has low zinc concentrations. Facilities with forklifts and higher volumes of truck traffic than those of these two monitored facilities may show higher zinc concentrations in runoff from loading dock and grounds areas.

The extent of zinc contributions from aerial deposition and landscape fertilizers is not known. Also, a variety of building materials can release zinc to stormwater runoff, but to a degree not generally known.

In urban areas, zinc in stormwater runoff other than from industrial facilities can include many sources. One that may be important, but largely unstudied, is zinc used for moss control on residential roofs.

Recommendations

Simple screening-level surveys of industrial facilities can be conducted by facility staff or Department of Ecology staff, as discussed in this report. A definitive determination of sources and their extent within a facility would require a more thorough investigation with the possible inclusion of sub-area sampling. In a general sense, a facility can be characterized as discharging higher than average zinc concentrations by applying the criteria of this study:

1. Concentrations higher than the action level of 372 µg/L, and
2. A mean concentration higher than 200 µg/L.

As a rough guideline, based on monitoring at two facilities, the breakpoint between roofs with high amounts of galvanized materials is about 3% - 5% or more of the total roof area. For example, a 100-ft x 100-ft roof (10,000 ft^2) supporting a galvanized box of 10-ft length, 10-ft width, by 5-ft height may be a source of high concentrations of zinc in its runoff.

Though not a part of this study, examples of possible measures to reduce zinc in stormwater runoff at an industrial facility might include:

- Using painted metal instead of galvanized metal for ventilator covers, ductwork, and other surfaces.
- Substituting vinyl-covered, chain-link fences for galvanized chain-link fences.
- Cleaning grounds and loading dock areas, particularly with heavy vehicular traffic.
- Repairing forklifts that leak hydraulic fluid.
- In cases where the source(s) are clearly identified, considering the implementation of best management practices to reduce zinc in runoff.

A more complete accounting of sources of zinc in industrial stormwater runoff will require additional information or research to:

- Determine the impact of tire particles on zinc in stormwater runoff.
- Determine the extent that galvanized downspouts and storm sewers contribute to zinc concentrations in stormwater runoff.
- Investigate the contribution of atmospheric deposition to stormwater runoff (though spatial variability has made this a difficult area of study).
- Consider the impact of zinc in stormwater from sources other than industrial facilities, such as commercial and retail facilities, as well as the residential use of zinc for moss control.

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Appendices

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Appendix A. Monitoring Precision Data

Parameter	Site	Date - 2005	Sample 1	Sample 2	RPD
Lab Duplicates					
Zinc, diss (µg/L)	DWSP2	4/29	156	155	0.6 %
TSS (mg/L)	LOADG	4/29	16	17	6.1 %
	ROOF	4/15	23	13	56 %
	DISCH	4/15	6 J	5 J	18 %
	DISCHRP	4/15	2 J	3 J	40 %
	PARKG	4/7	16	17	10 %
	PARKG3	3/29	73	77	10 %
Field Replicates					
TSS (mg/L)	park	4/15	30 J	21 J	35%
	pvcroof	4/15	7 J	1 UJ	150%
	alroof	4/15	22 J	1 UJ	182%
	disch	4/15	6 J	2 J	100%
Zinc, TR (µg/L)	disch	4/7	136	138	2%
	disch	4/15	100	98.3	2%
	alroof	4/15	150	94.8	45%
	pvcroof	4/15	72.1	63.4	13%
	park	4/15	57.3	31.4	58%
	load dock	4/15	118	124	5%
Zinc, diss (µg/L)	disch	4/7	128	128	0%
	disch	4/15	103	102	1%
	alroof	4/15	123	83.6	38%
	pvcroof	4/15	77.3	69.5	11%
	park	4/15	38.4	23.3	49%
	load dock	4/15	71.2	71.9	1%

Appendix A (cont'd). Monitoring Precision Data

	Date - 2005	Zinc TR µg/L	Zinc Diss µg/L
Field Blanks			
Transfer Blank	3/26 3/29 4/29	5.0 U 5.0 U 5.0 U	
Filter Blank	3/29 4/29		2.9 1.2
Aluminum Foil Blank	4/15 4/29	5.0 U 5.0 U	

* - Relative percent difference, RPD is equal to the difference between sample results divided by the mean of the two values, expressed as a percentage.

Appendix B. Inventory Field Form, Zinc Sources to Runoff at Industrial Facilities

Zinc Source Inventory Form

1. Zinc data (self monitoring)

2. SWPP map (for roof, parking, loading dock areas, and chain-link length)

3. Sampling point
   a. Specific areas contributing
   b. Appropriate (worst case)?

4. Roof
   a. Material
   b. Galvanized HVAC, ventilator housings, etc.
   c. Downspouts

5. Stormwater Conveyance
   a. Gutter material
   b. Downspout material
   c. Storm sewer material

6. Building siding material

7. Chain-link fence
   a. Material
   b. Length into sampling area

8. Ground activity
   a. Hydraulic fluid / Tire dust (forklifts/heavy equipment)
   b. Motor oil (cars and trucks)
   c. Other sources (manufacture or storage)

9. Run-on of stormwater from other properties onto facility property.

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Appendix C. Inventory Summaries

Facility #: 1	**Type of Facility:** Large recycling transfer station

Self-Monitoring

	Yes/No
Reported Zinc Concentrations: 22 24 58 61	
Self-monitoring Sampled Area(s) – Appropriate? The entire drainage from this large site is directed to a vegetated pond on property. **Sampling and Reporting – Appropriate?** Sampled from downstream end of vegetated pond.	Yes Yes

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	**Self-Sampled?**
Parking Lot: Parking is for only a few vehicles in a facility of many acres.	None - L	√
Loading Dock: N/A		
Roof: Painted metal roof. Building footprint is very small relative to facility drainage area. Building has small area of galvanized materials.	None - L	√
Grounds: Grounds partially paved, partially unpaved. Area is several acres with most of grounds experiencing no truck or other traffic. Traffic at the site is minimal relative to area.	L	√

Appendix C. Inventory Summaries (cont'd)

Facility #: 2	**Type of Facility:** Outdoor storage of machinery and parts

Self-Monitoring

	Yes/No
Reported Zinc Concentrations (µg/L): 120 20 39 110 44	
Self-monitoring Sampled Area(s) – Appropriate? Sampled area includes drainage from most of facility including most of roof. Potentially large source of run-on (not observed during survey as conditions were dry): Steep wooded hillside adjacent to site, approximately 1.5 times the facility area. Hillside ends top of curb at perimeter of site. Runoff from hillside onto the site may be responsible for unusually low zinc concentrations reported from this facility.	?
Sampling and Reporting – Appropriate? Sampling at bottom of catch basin.	Yes

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	Self-Sampled?
Parking: Small area relative to facility.	L - M	√
Loading Dock: (See "Grounds," below.)	M	√
Roof: Painted metal roof. Roof has moderate-to-high relative amount of galvanized materials.	M – H	√
Grounds: Large, iron parts are stored on paved area on site. No visible oil on grounds. Concrete storm sewer.	M	√

Appendix C. Inventory Summaries (cont'd)

Facility #: 3	**Type of Facility:** Container production (wooden)

Self-Monitoring

	Yes/No
Reported Zinc Concentrations(µg/L): 223 2.09 3.40	
Self-monitoring Sampled Area(s) – Appropriate? Sample includes most of facility area. Sampled from bottom of final catch basin.	Yes
Sampling and Reporting – Appropriate? Two reported zinc concentrations are outliers, a factor of 10 below zinc concentrations found elsewhere in this study.	No

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	Self-Sampled?
Parking Lot: Typical of facilities surveyed.	L - M	√
Loading Dock: Loading dock is small area, relative to paved grounds (see "Grounds," below.)	M - H	√
Roof: Painted metal roofs. Little or no galvanized materials. Downspouts are plastic and galvanized.	L	√
Grounds: Lumber stored outside. Forklifts present but no leakage spots visible.	M - H	√

Appendix C. Inventory Summaries (cont'd)

Facility #: 4	**Type of Facility:** Concrete Products

Self-Monitoring

	Yes/No
Reported Zinc Concentrations (µg/L): 50 130 100 90 50 70	
Self-monitoring Sampled Area(s) – Appropriate? Sample may not be of facility stormwater runoff (see below):	No
Sampling and Reporting – Appropriate? Sampling point: a manhole vault adjacent to grassy swale for final discharge. A 20 ft pipe connects the swale to the manhole, but facility personnel report water in the swale never rises to pipe level. It appears that what is sampled may not be stormwater runoff from the facility. Sample timing: Permittee systematically samples the second or third day of rainfall, not the first hour of discharge as required by the ISGP.	No

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	**Self-Sampled?**
Parking Lot: Parking area is unusually clean.	L	**?**
Loading Dock: Considerable truck traffic. Forklifts in use.	M - H	**?**
Roof: Painted metal roof. No HVAC or galvanized materials on roof.	L	**?**
Grounds: Considerable truck traffic.	M - H	**?**

Appendix C. Inventory Summaries (cont'd)

Facility #: 5	**Type of Facility:** Metal machining (non zinc-containing)

Self-Monitoring

	Yes/No
Reported Zinc Concentrations(µg/L): 100 120 40	
Self-monitoring Sampled Area(s) – Appropriate? Sampling coverage is excellent: three locations with stormwater runoff from the facility. But see inappropriate reporting, below:	Yes
Sampling and Reporting – Appropriate? Records on site include zinc concentrations for five quarters (five days). Only one of these five days was reported to Ecology: the day with the lowest pollutant concentrations.	No

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	Self-Sampled?
Parking Lot: Parking lot for 350 employees. Cars are late model. Parking lot appears clean. Parking lot is swept monthly.	L - M	√
Loading Dock: Typical of loading docks surveyed.	M - H	√
Roof: Roof runoff comprises approximately half of stormwater discharge sampled. PVC downspouts. Storm sewer pipe is concrete. Considerable galvanized materials on roof: The facility is gradually replacing painted vent hoods with galvanized (currently 12 - 5ft x 5ft galvanized vent hoods on roof). Flat roof. Torchdown (bitumen asphalt modified with polymer) with aluminum paint coating.	M - H	√
Grounds: (see parking lot and loading dock, above.)		√

Appendix C. Inventory Summaries (cont'd)

Facility #: 6	**Type of Facility:** Food products

Self-Monitoring

	Yes/No
Reported Zinc Concentrations (µg/L): 77 63 94 160	
Self-monitoring Sampled Area(s) – Appropriate? All but a small portion of the site drains to this point. Includes roof runoff.	Yes
Sampling and Reporting – Appropriate? Sample site is final stormwater vault at edge of property. Sampling at bottom of catch basin catches runoff from catch basins throughout facility via stormwater sewer.	Yes

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	**Self-Sampled?**
Parking Lot: Car parking has some oil spots visible.	M - H	√
Loading Dock: (see "Grounds," below.)	M - H	√
Roof: Flat roof of composite material. Low/medium amount galvanized materials on roof, but minor relative to 20 acre site. Downspouts are PVC, to sewer to sampling site. Storm sewer is galvanized but well-coated with tightly held brown organic material.	L	√
Grounds / Runoff Treatment: Some 150 semi truck/trailers are based at the site, all parked each night. Moderate/high hydraulic equipment use. Some motor oil on ground in truck parking area. Puddle with slight sheen visible. Pavement sweeper on twice-monthly schedule. **Runoff Treatment**: Catch basin inserts with filter fabric in 12 catch basins. Facility personnel report they are effective, turning black and clogging, replaced after approximately every 3 inches of rainfall.	M - H (Responsible for low Zinc in runoff?)	√

Appendix C. Inventory Summaries (cont'd)

Facility #: 7	**Type of Facility:** Wrecking yard

Self-Monitoring

	Yes/No
Reported Zinc Concentrations (µg/L): 58 28 118 104 205	
Self-monitoring Sampled Area(s) – Appropriate? Approximately two-thirds of property drains to sample point. Roof goes to drainfield, is not sampled. **Sampling and Reporting – Appropriate?** Sampling point at downstream end of grassy swale, about 20 feet wide and 120 feet long. Swale has thick growth of grass. Facility runoff is sampled "when it has rained for awhile." This is not unusual among facilities but excludes sampling during first hour of discharge, required by the ISGP.	Yes Yes No

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	Self-Sampled?
Parking Lot: Typical. Small relative to site.	L - M	√
Loading Dock: N/A	--	
Roof: Painted metal roof. Stormwater runoff from roof goes to drainfield, does not contribute to runoff.	--	
Grounds/Runoff Treatment: Area is part paved, part gravel. Gravel shows no fluid leakage from wrecked vehicles. Two sides of property have chain-link fence with runoff onto property. Removal of all vehicle fluids is done inside a building with a floor sloping towards center of building with a sump. It is well established that grassy swales significantly remove solids and metals.	L - M	√

Appendix C. Inventory Summaries (cont'd)

Facility #: 8	**Type of Facility:** Welding

Self-Monitoring

	Yes/No
Reported Zinc Concentrations (µg/L): *First quarter '04 and earlier:* 794 530 *3rd quarter '04 and later:* 89 25 280 25	
Self-monitoring Sampled Area(s) – Appropriate? Sampled area is along the front of the facility where forklifts operate: about 120 ft x 80 ft. Roof is also in sampled area. **Sampling and Reporting – Appropriate?**	Yes Yes

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	**Self-Sampled?**
Parking Lot: Typical (not included in sampling area.)	M	
Loading Dock: (See "Grounds," below.)		
Roof: Little or no galvanized material on roof. Roof drains to sampled area. A painted metal roof (?) Downspouts are aluminum.	L	√
Grounds: Two forklifts working intensively in the same small area that is the sample area. Typically, one to three tractor-trailers daily. Facility manager reports that before mid-2004, forklifts were old, in poor condition, and leaking considerably, to the point that hydraulic fluid on inside floor was a slip/trip hazard. He sometimes saw a sheen when sampling. In mid-2004, forklifts were repaired/maintained. Self-reporting shows corresponding change from high zinc concentrations to low between first and third quarters 2004.	H (in past) Now L - M	√

Appendix C. Inventory Summaries (cont'd)

Facility #: 9	**Type of Facility:** Metals machining (no plating)

Self-Monitoring

	Yes/No
Reported Zinc Concentrations (µg/L): 106	
Self-monitoring Sampled Area(s) – Appropriate? Most of facility area including most of roof area sampled. **Sampling and Reporting – Appropriate?** Only one quarter sampled – one data point. Facility staff attribute this to personnel turnover.	Yes Yes

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	**Self-Sampled?**
Parking Lot: Parking lot puddles, is cleaned often.	L - M	√
Loading Dock: (See "Grounds," below)	L - M	√
Roof: Composite roof. No galvanized on roof. Downspouts plastic.	L	√
Grounds: Three forklifts, but no leaks evident. Little truck traffic. Storm sewer is plastic.	L - M	√

Appendix C. Inventory Summaries (cont'd)

Facility #: 10	**Type of Facility:** Coating materials

Self-Monitoring

	Yes/No
Reported Zinc Concentrations (µg/L): 49 169 224 44	
Self-monitoring Sampled Area(s) – Appropriate? Runoff from roof and loading dock, not parking lot, are sampled.	Yes
Sampling and Reporting – Appropriate? Sampling site is from lip of catch basin receiving flow from roof and loading dock. The facility is in an industrial park strip-building with a continuous loading dock behind buildings. Some of neighbor facilities' flow may be included, in sample, but unavoidable.	Yes

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	Self-Sampled?
Parking Lot: Only a few spaces.	L - M	
Loading Dock: Four tankers per week (low usage)	L - M	√
Roof: Flat roof. (Torchdown with aluminum paint.) Relatively low galvanized area on roof: (One galvanized stack on roof).	M	√
Grounds: A small facility, loading and parking areas comprise grounds		√

Appendix C. Inventory Summaries (cont'd)

Facility #: 11	**Type of Facility:** Supplier of Gases

Self-Monitoring

	Yes/No
Reported Zinc Concentrations (µg/L): 199 52	--
Self-monitoring Sampled Area(s) – Appropriate? The 3 sampled areas are appropriate in that they represent all major stormwater runoff flows.	Yes
Sampling and Reporting – Appropriate? Permittee has reported *lowest* of 3 sample site's data. 52 µg/L at outfall 1 was reported for 3rd quarter 2004. 240 µg/L and 640 µg/L was measured that day for Outfalls 2 and 3 but not reported.	No

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	**Self-Sampled?**
Parking Lot: Ground is asphalt. It is clean (from recent rains?). They used to sweep but do no longer. Potential for oil in runoff: low. Approximately 140 ft of galvanized fence through middle of property, draining to drainage area 1.	L - M	√
Loading Dock: Moderate level of truck loading.	M - H	√
Roof: Painted steel roofs. No HVAC nor other galvanized materials on roof. Downspouts are all aluminum or painted (no galvanized).	L	√
Grounds: Some scrap, aluminum, non-zinc. Puget Power transformer and tower onsite with large area of galvanized metal.	H	√

Appendix C. Inventory Summaries (cont'd)

Facility #: 12	**Type of Facility:** Plumbing materials

Self-Monitoring

	Yes/No
Reported Zinc Concentrations (µg/L): 163 250 61 174 81 35	
Self-monitoring Sampled Area(s) – Appropriate? Sampled area is a small portion of parking lot and small portion of the roof that has no galvanized HVAC or other materials. Most of roof, not included in sampled area, has large area of galvanized materials. Original monitoring site was ditch adjacent to property: results were high zinc concentrations. This original monitoring site included most of facility area. Manager said he changed sampling point because ditch may have included upstream runoff from other industries. He indicated he changed sampling site to this one in order to show lower metals concentrations.	No
Sampling and Reporting – Appropriate? Sample drawn from runoff from a small portion of facility as it enters ditch. The facility changed its sampling point to exclude most of facility area after first showing high concentrations.	No

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	Self-Sampled?
Parking Lot: Parking area appears clean. Parking area appears much cleaner than paved areas not included at the sampling point, which had considerable scrap and debris.	M	√
Loading Dock: Loading dock area less clean than typical.	M - H	
Roof: Two roof materials: painted metal & "torchdown" (painted bitumen asphalt). Roof has large area of galvanized HVAC as does the ground. The sampling site does not include these areas.	H	
Grounds: Considerable materials and debris on significant area of grounds.	M - H	

Appendix C. Inventory Summaries (cont'd)

Facility #: 13	**Type of Facility:** Beverages wholesale

Self-Monitoring

	Yes/No
Reported Zinc Concentrations (µg/L): 102 197	
Self-monitoring Sampled Area(s) – Appropriate? Sample point catches essentially all of runoff from paved surfaces and roof.	Yes
Sampling and Reporting – Appropriate? Self-monitoring sample is taken from bottom of catch basin.	Yes

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	**Self-Sampled?**
Parking Lot: Parking area is clean.	L - M	√
Loading Dock: No hydraulic equipment in use. Loading dock is clean.	L - M	√
Roof: No galvanized materials on roof.	L	√
Grounds/Runoff Treatment: No industrial activities or material storage on grounds. Storm sewer pipe is galvanized (spiral), but 30 years old – the useful life of galvanized materials: zinc runoff may be low. Two catch basins have catch basin inserts with "Ultra-Urban Filter" with Oars® (smart sponge filters). Literature indicates insert type substantially removes metals. Self-reporting zinc concentrations relatively low, compared with other facilities, and survey of sources shows lesser sources than other facilities.	M	√

Appendix C. Inventory Summaries (cont'd)

Facility #: 14	**Type of Facility:** Package Design/Development

Self-Monitoring

	Yes/No
Reported Zinc Concentrations(µg/L): 170 70 140 310	--
Self-monitoring Sampled Area(s) – Appropriate? Less than 10% of drainage area sampled. A portion of the employee parking lot was the only area of the facility for which runoff was sampled. Roof runoff, with considerable HVAC on top, is not included in the sample. **Sampling and Reporting – Appropriate?** (see above)	No No

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	**Self-Sampled?**
Parking Lot: Typical parking lot. A small portion of parking lot comprised all of sample.	L - M	√
Loading Dock: (See "Grounds," below)		
Roof: Considerable galvanized HVAC on roof, but roof not sampled.	H	
Grounds: Larger portion of facility exposed to truck traffic than is typical of other facilities. Hydraulic equipment: forklifts, truck lifts.	M - H	

Appendix C. Inventory Summaries (cont'd)

Facility #: 15	**Type of Facility:** Truck trailer operations

Self-Monitoring

	Yes/No
Reported Zinc Concentrations(µg/L): 180 165 167 374 208	
Self-monitoring Sampled Area(s) – Appropriate? Sample site is down in catch basin, as runoff leaves property. Storm sewer pipe is galvanized (spiral). **Sampling and Reporting – Appropriate?**	 Yes Yes

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	**Self-Sampled?**
Parking Lot: Typical.	L - M	√
Loading Dock: Loading dock is busy: considerable truck traffic and forklift activity. Forklifts appear fairly new. Pavement at loading dock has considerable buildup of dark material.	H	√
Roof: Roof is torchdown with aluminum paint. No galvanized materials on roof. Roof runs off to pavement, then to sampling point.	L	√
Grounds: No industrial activities or materials stored on grounds.	M	√

Appendix C. Inventory Summaries (cont'd)

Facility #: 16	**Type of Facility:** Machine shop (non-galvanized products)

Self-Monitoring

	Yes/No
Reported Zinc Concentrations(µg/L): *1st quarter '04 and earlier:* 430 200 *2nd quarter '04:* 46	
Self-monitoring Sampled Area(s) – Appropriate? Drainage area for sample site is roughly 75% pavement, 25% roof. Sample is collected at the lip of a catch basin in front of the property on the edge of a city street. **Sampling and Reporting – Appropriate?**	Yes Yes

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	Self-Sampled?
Parking Lot: Typical, small lot. Not included in sampled area.	M	
Loading Dock: (See "grounds," below.)	H, then L	√
Roof: Little or no galvanized materials.	L	√
Grounds: Three forklifts operate at facility. Personnel cleaned grounds between 1st and 2nd quarter '04. Self-reporting numbers appear to reflect this. There had been over three years of accumulation, including wood chips. It may be that wood chips soaked up motor oils and hydraulic fluids during dry periods, then were washed off and released to runoff during storm events.	H, then L	√

Appendix C. Inventory Summaries (cont'd)

Facility #: 17	**Type of Facility:** Bakery products

Self-Monitoring

	Yes/No
Reported Zinc Concentrations(µg/L): 556 212 184 146 102	
Self-monitoring Sampled Area(s) – Appropriate? Initial monitoring site (556 µg/L) adjacent to neighbor's facility with run-on from neighbor's forklifts. Subsequent samples include facility's parking area only, not loading dock area. **Sampling and Reporting – Appropriate?**	No (see above)

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	**Self-Sampled?**
Parking Lot: Clean. Swept once per month.	L	√
Loading Dock: High traffic forklift operations. The facility manager says it is too difficult to sample.	M - H	
Roof: Substantial area is galvanized (includes fan boxes: approximately 7ft x 7ft x 2.5 ft high). Roof goes to ground and is not sampled.	M – H (but not in runoff)	
Grounds: No industrial activities or materials stored on grounds.		√

Appendix C. Inventory Summaries (cont'd)

Facility #: 18	**Type of Facility:** Food products

Self-Monitoring

	Yes/No
Reported Zinc Concentrations(µg/L): 130 360 250 240 390	
Self-monitoring Sampled Area(s) – Appropriate? Sample from vault that includes flow from most of roof, parking lot, and loading dock. **Sampling and Reporting – Appropriate?**	Yes Yes

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	**Self-Sampled?**
Parking Lot: Some oil spots visible.	M	√
Loading Dock: Little to moderate traffic. No forklifts.	L - M	√
Roof: Higher than average relative area of galvanized materials on roof.	M - H	√
Grounds: All industrial activities indoors. No materials stored on grounds.		√

Appendix C. Inventory Summaries (cont'd)

Facility #: 19	**Type of Facility:** Manufacture, storage of concrete materials

Self-Monitoring

	Yes/No
Reported Zinc Concentrations(µg/L): 684 162 192 67	
Self-monitoring Sampled Area(s) – Appropriate? Most of facility area is included at stormwater discharge sampling point.	Yes
Sampling and Reporting – Appropriate?	Yes

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	**Self-Sampled?**
Parking Lot: Concrete materials stored outside.	M	√
Loading Dock: Forklifts and a bulldozer on site.	M	√
Roof: Roofs are fiber glass/ painted metal.	L	√
Grounds: Concrete materials stored on grounds.	M	√

Appendix C. Inventory Summaries (cont'd)

Facility #: 20	**Type of Facility:** Bus storage

Self-Monitoring

	Yes/No
Reported Zinc Concentrations(µg/L): 195 318 266 239 213 462	
Self-monitoring Sampled Area(s) – Appropriate? At lowest catch basin, as storm sewer leaves facility. **Sampling and Reporting – Appropriate?** Sampling from bottom of catch basin. Storm sewer material not known (galvanized?)	 Yes Yes

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	**Self-Sampled?**
Parking Lot: Typical employee parking.	L - M	√
Loading Dock: N/A		
Roof: Painted metal roof. The only source of galvanized on roof is 6ft x 6ft horizontal surface. Downspouts are aluminum.	L	√
Grounds: Buses, but no materials stored on grounds. Facility handles approximately 75 buses. Gravel with impervious (plastic) barrier beneath. Gravel appears clean. The operation of large number of vehicles can be expected to be a source of motor oil and tire zinc.	M	√

Appendix C. Inventory Summaries (cont'd)

Facility #: 21	**Type of Facility:** Manufacture of waterproof coatings

Self-Monitoring

	Yes/No
Reported Zinc Concentrations(µg/L): 43 567 490 55	
Self-monitoring Sampled Area(s) – Appropriate? Facility personnel report discharge point is under water so sample is only of roofs, no paved areas. More than 50% of the facility area is roof, and the loading dock is covered, so in this case monitoring roof alone is appropriate.	Yes
Sampling and Reporting – Appropriate? First day of rain is systematically excluded from sampling. It is the first day that ISGP calls for to be sampled.	No

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	**Self-Sampled?**
Parking Lot: Typical.	L - M	
Loading Dock: Typical	M	
Roof: One roof has large area of galvanized ductwork (baghouse filter no longer in service). The other roof is identical but without galvanized materials. Self-monitoring has been alternating between the two roofs.	L/H (alternating)	√
Grounds: No industrial processes or materials stored on grounds.		

Appendix C. Inventory Summaries (cont'd)

Facility #: 22	**Type of Facility:** Aluminum manufacturing

Self-Monitoring

	Yes/No
Reported Zinc Concentrations(µg/L): 190 210 484 477 121 256	
Self-monitoring Sampled Area(s) – Appropriate? Roof and loading dock are in sampled area.	Yes
Sampling and Reporting – Appropriate?	Yes

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	**Self-Sampled?**
Parking Lot: Typical.	L - M	
Loading Dock: Minor traffic (one to two trucks daily). Some water puddles in loading dock area but no sheen visible.	L - M	√
Roof: Considerable area of galvanized ductwork on roof (roof approximately 35 years old). Ductwork is painted, it appears with zinc-rich paint to restore galvanic protection.	M - H	√
Grounds: No industrial activities or materials stored on grounds.	L - M	√

Appendix C. Inventory Summaries (cont'd)

Facility #: 23	**Type of Facility:** Trucking

Self-Monitoring

	Yes/No
Reported Zinc Concentrations(µg/L): 239 399 604 119 194	
Self-monitoring Sampled Area(s) – Appropriate? Most of facility including most of pavement to sampling spot.	Yes
Sampling and Reporting – Appropriate? Sample site is culvert as it enters pond.	Yes

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	**Self-Sampled?**
Parking Lot: Typical.	M	√
Loading Dock: (See "Grounds," below.)	--	√
Roof: Torchdown (modified bitumen asphalt) with aluminized paint. Galvanized blowers on roof.	M	√
Grounds: Approximately 20 semi-trucks on site. Lot requires tight-radius turns. Oil spots on truck parking spaces. 300 ft of chain-link fence drains to sample spot.	H	√

Appendix C. Inventory Summaries (cont'd)

Facility #: 24	**Type of Facility:** Trucking

Self-Monitoring

	Yes/No
Reported Zinc Concentrations(µg/L): 619 180 347 181	
Self-monitoring Sampled Area(s) – Appropriate? Sampling area includes roofs and flow from all catch basins. **Sampling and Reporting – Appropriate?** At bottom of catch basin.	Yes Yes

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	Self-Sampled?
Parking Lot: Typical.	M	√
Loading Dock: (see "Grounds," below)	--	√
Roof: Roof is well coated, little or no galvanized. Roof drains to catch basin, then to sampling point.	L	√
Grounds: Heavy semi-truck traffic. Lot requires tight-radius turns. Approximately 30 truck parking spaces and 30 oil spots (about 3ft x 6ft each). No hydraulic equipment. Truck wash on site does not contribute to runoff or go to storm sewer.	H	√

Appendix C. Inventory Summaries (cont'd)

Facility #: 25	**Type of Facility:** Manufacture of polymer (plastic) products

Self-Monitoring

	Yes/No
Reported Zinc Concentrations(μg/L): 680 170 300 340	
Self-monitoring Sampled Area(s) – Appropriate? Most of the site is in the area of sampled stormwater discharge. **Sampling and Reporting – Appropriate?**	 Yes Yes

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	Self-Sampled?
Parking Lot: Parking lot appears clean. Mostly late-model cars.	L	√
Loading Dock: Loading dock appears clean. No hydraulic equipment on site. Sweeper is used to clean pavement.	L	√
Roof: Torchdown (modified bitumen asphalt), aluminum coating. Some roof to sample location. Newer roof to ground, as required by city of Kent. An unusually large area of galvanized on roof: 34 galvanized turbines and box stands on factory roof only: est. 1360 sq ft total Factory roof area approximately 9,300 sq ft Area of galvanized as percent of roof: 15%: Estimate = 8,000 μg/L x 0.15 = 1,200 μg/L from factory roof (based on conservative estimate of typical galvanized runoff zinc concentration of 8,000 μg/L, from literature).	H	√
Grounds: No industrial activities or materials stored on grounds.	L	√

Appendix C. Inventory Summaries (cont'd)

Facility #: 26	**Type of Facility:** Delivery trucks

Self-Monitoring

	Yes/No
Reported Zinc Concentrations(µg/L): 700 338 396 385	
Self-monitoring Sampled Area(s) – Appropriate? Sampled area is most of facility area. **Sampling and Reporting – Appropriate?**	 Yes Yes

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	**Self-Sampled?**
Parking Lot: Typical.	L	√
Loading Dock: Loading docks are under overhanging roofs to reduce/eliminate runoff.	L	√
Roof: Dock and shop roofs are fully galvanized. Office roof is bitumen asphalt, with no galvanized material. (This is the only major roof area of galvanized metal of all facilities in this survey).	H	√
Grounds: Parking area for trucks is large, with much of area open, clean, and unused. Other parking area appears clean. Overall, unusually clean. Storm sewer is plastic. No industrial activities or materials stored on ground.	L - M	√

Appendix C. Inventory Summaries (cont'd)

Facility #: 27	**Type of Facility:** Cleaning supplies

Self-Monitoring

	Yes/No
Reported Zinc Concentrations(µg/L): 463	
Self-monitoring Sampled Area(s) – Appropriate? Sampling area includes loading dock and roof.	Yes
Sampling and Reporting – Appropriate? Sample is collected from lip of catch-basin at loading dock behind buildings. Some of neighboring facilities' runoff may be in sample, but all facilities appear to be similar, with clean loading docks.	Yes

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	**Self-Sampled?**
Parking Lot: Small parking lot and small grassy strips (about 100ft x 12ft on side of building (6 facilities per building). Facility personnel suggest zinc is from fertilizer of grassy strip. No chain-link fence.	L	
Loading Dock: Loading docks continuous from one facility to the next (behind strip-building). Loading docks appear clean.	M	√
Roof: Composition roof with virtually no galvanized. Walls of building are painted concrete, recent construction.	L	√
Grounds: No industrial activities or materials stored on grounds.	M	√
Comments: Facility is in neat, newer industrial park strip building of small, light industries. From this survey, this would be expected to be a facility with low to medium zinc concentrations in stormwater discharge. There are no apparent sources of high zinc.		

Appendix C. Inventory Summaries (cont'd)

Facility #: 28	**Type of Facility:** Metal working (non-zinc)

Self-Monitoring

	Yes/No
Reported Zinc Concentrations(µg/L): 1,500 234 152	
Self-monitoring Sampled Area(s) – Appropriate? Parking lot and loading dock comprise the runoff of sampled area. **Sampling and Reporting – Appropriate?** Sampling is at lip of catch basin.	Yes Yes

Zinc Sources (rating relative to sources at all 28 facilities)

	L M H	**Self-Sampled?**
Parking Lot: Typical in appearance. Fairly clean.	L - M	√
Loading Dock: Continuous forklift traffic and heavy truck traffic.	M - H	√
Roof: Roof goes to ground, not in stormwater discharge.	--	
Grounds: No industrial activities or materials stored on ground.	L	√